Planning: Heuristics and CSP Planning

Computer Science cpsc322, Lecture 18

(Textbook Chpt 8)

February, 13, 2009

Lecture Overview

- **Recap: Planning Representation and Forward algorithm**
- Heuristics
- CSP Planning

Standard Search vs. Specific R&R systems

Constraint Satisfaction (Problems):

- State: assignments of values to a subset of the variables
- Successor function: assign values to a "free" variable
- Goal test: set of constraints
- Solution: possible world that satisfies the constraints
- Heuristic function: *none (all solutions at the same distance from start)*

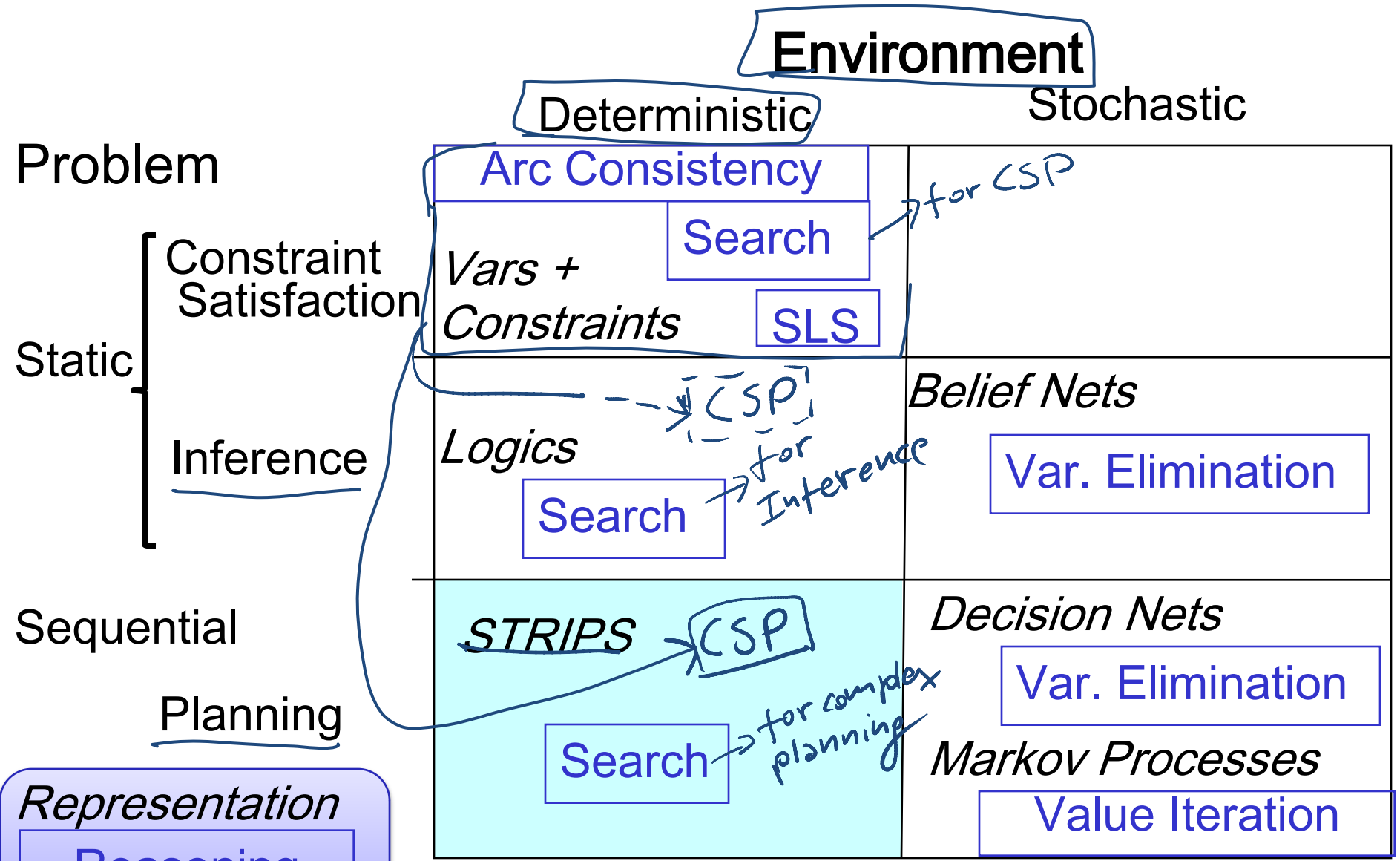
Planning :

- State possible world
- Successor function states resulting from valid actions
- Goal test assignment to subset of vars
- Solution sequence of actions
- Heuristic function TODAY

Inference

- State
- Successor function
- Goal test
- Solution
- Heuristic function

Modules we'll cover in this course: R&Rsys



Lecture Overview

- Recap: Planning Representation and Forward algorithm
- Heuristics for forward planning
- CSP Planning

Heuristics for Forward Planning

Heuristic function: estimate of the distance form a state to the goal

In planning this is the…# action…

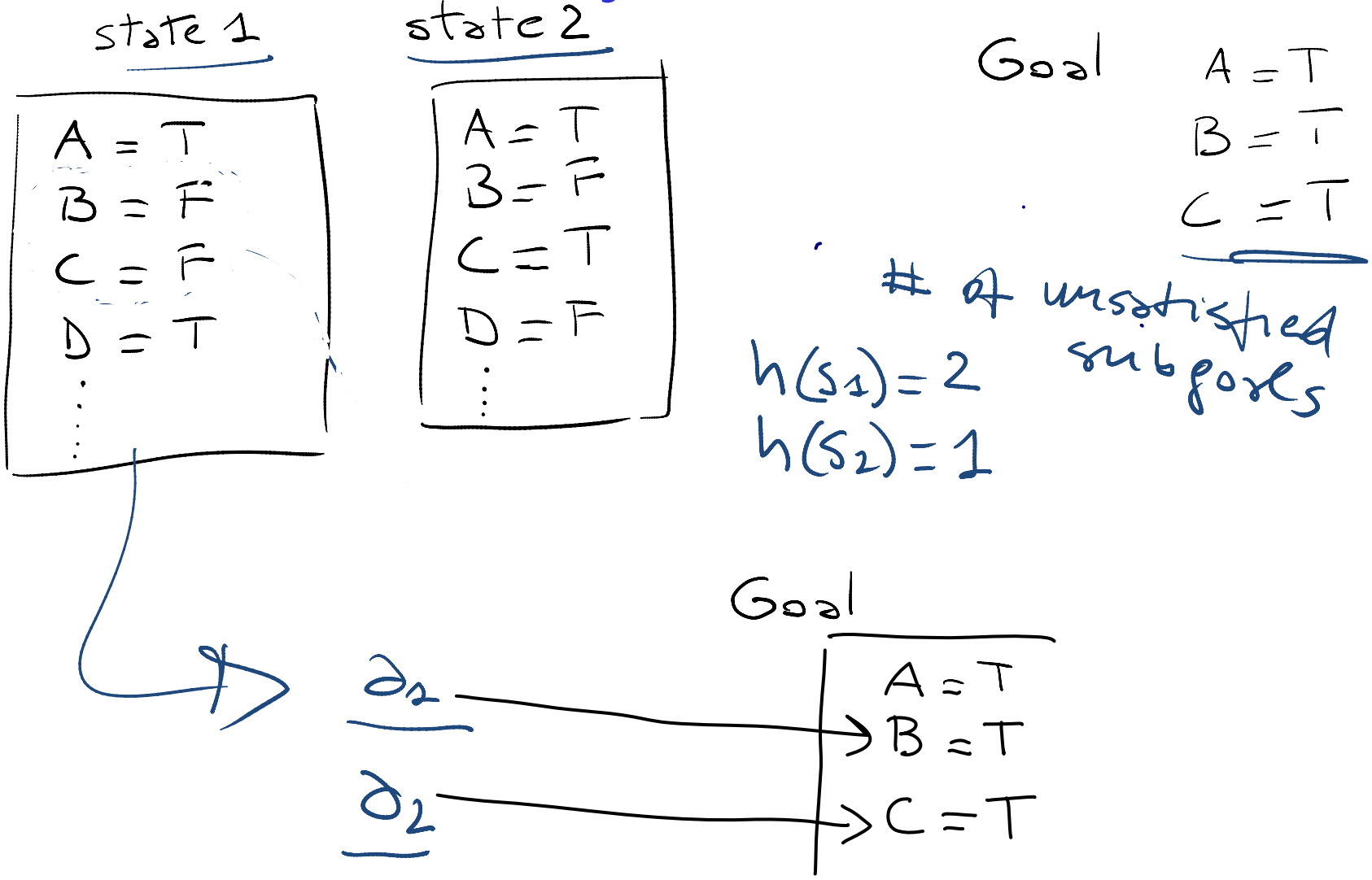
Two simplifications in the representation:

- All features are binary: T / F
- Goals and preconditions can only be assignments to T

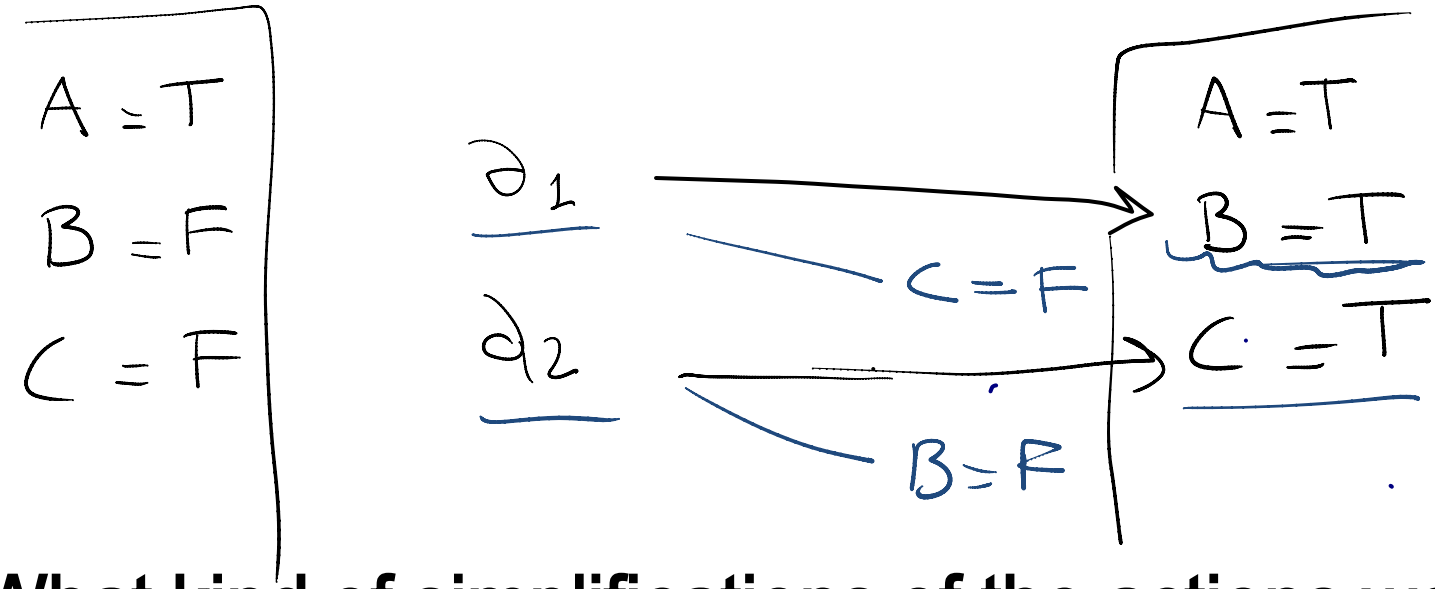
And a Def. a subgoal is a particular assignment in the goal e.g., if the goal is <A=T, B=T, C=T> then….

subgoal A=T subgoal B=T subgoal C=T

Heuristics for Forward Planning: Any ideas?



Heuristics for Forward Planning (cont')



What kind of simplifications of the actions would justify our proposal for h?

a) We have removed all ... preconditions

b) We have removed all ... negative effects

c) We assume no action can achieve ... both

⇒ inadmissible

Heuristics for Forward Planning: empty-delete-list

(c) make the heuristic inadmissible

(a) is a too strong simplification which makes the heuristic too weak

So

- **We only relax the problem according to (…b…)**

i.e., we remove all the effects that make a variable F

Action *a* effects (~~B=F~~, C=T)

- **But then how do we compute the heuristic?**

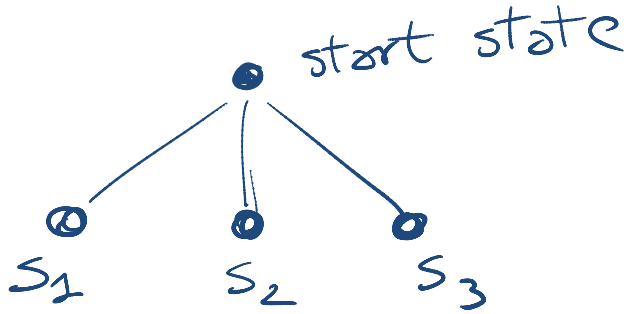
find plan with simplified representation

This is often fast enough to be worthwhile

see next slides

- **empty-delete-list heuristics with forward planning is currently considered a very successful strategy**

Empty-delete in practice



to compute $h(s_i)$, run forward planner with s_i as start state, with the same goal as the original problem but with all the actions with the negative effects removed.

So to compute h (for a given state) we need to solve a planning problem (but a simpler one!)

You may need to do this MANY times

Lecture Overview

- Recap: Planning Representation and Forward algorithm
- Heuristics for forward planning
- **CSP Planning**

Planning as a CSP

- An alternative approach to planning is to set up a planning problem as a CSP!

- We simply reformulate a STRIPS model as a set of variables and constraints

- Once this is done we can even express additional aspects of our problem (as additional constraints)

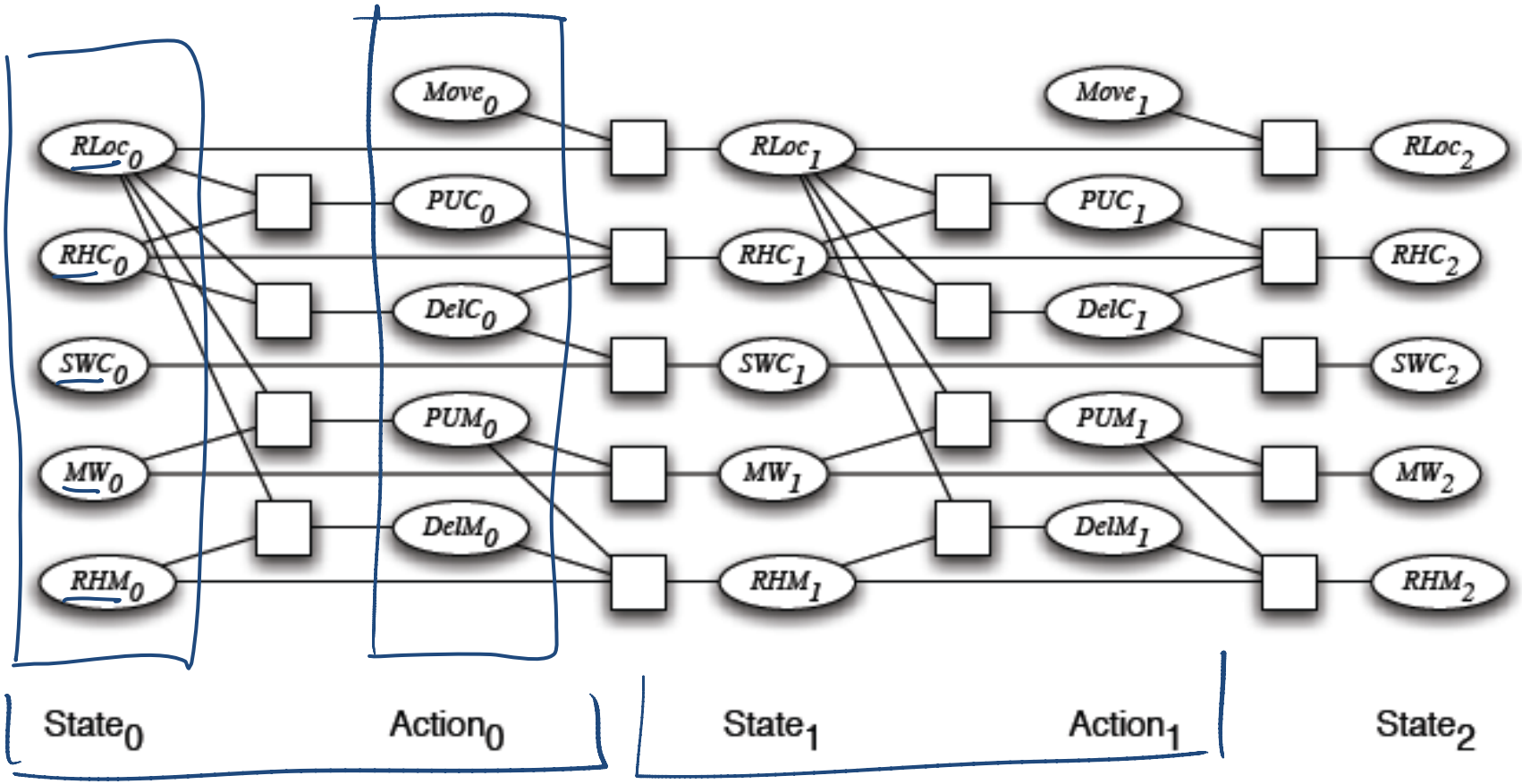
e.g., see Practice Exercise UBC commuting "*careAboutEnvironment*" constraint

Planning as a CSP: Variables

- We need to "unroll the plan" for a fixed number of steps
  - this is called the horizon

- To do this with a horizon of k:
  - construct a CSP variable for each STRIPS variable at each time step from 0 to k
  - construct a boolean CSP variable for each STRIPS action at each time step from 0 to k - 1.

CSP Planning: Robot Example

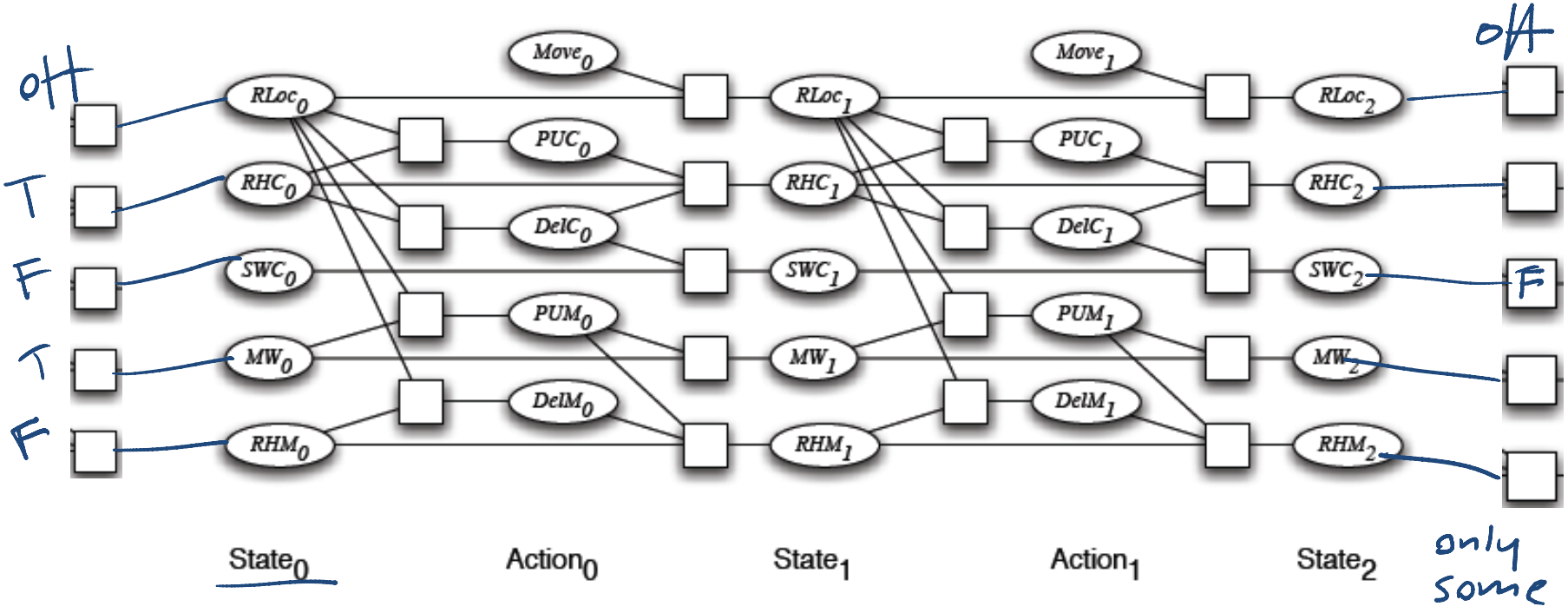


Variables for actions …. T F

K = 2

CSP Planning: Initial and Goal Constraints

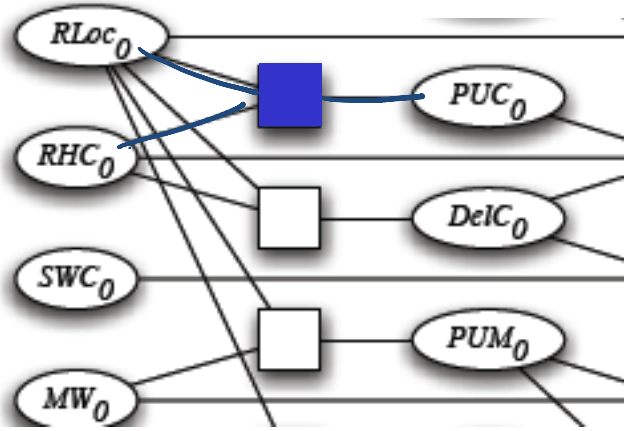
- initial state constraints constrain the state variables at time 0
- goal constraints constrain the state variables at time *k*



CSP Planning: Prec. Constraints

As usual, we have to express the **preconditions** and **effects** of actions:

- precondition constraints
  - hold between state variables at time *t* and action variables at time *t*
  - specify when actions may be taken

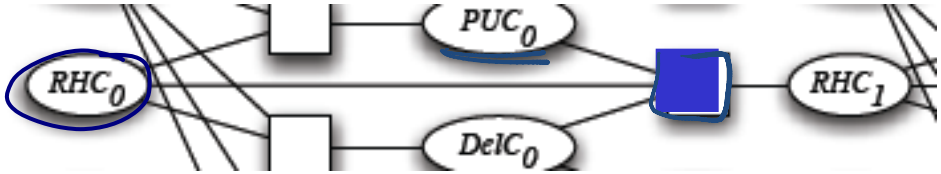


PUC_0

$RLoc_0$	RHC_0	PUC_0
cs	T	F
cs	F	T
cs	F	F
mr	*	F
lab	*	F
off	*	F

CSP Planning: Effect Constraints

- effect constraints
  - between state variables at time *t*, action variables at time t and state variables at time *t* + 1
  - explain how a state variable at time *t* + 1 is affected by the action(s) taken at time *t* and by its own value at time *t*



RHC_i	$DelC_i$	PUC_i	RHC_{i+1}
T	T	T	T
T	T	F	F
T	F	T	T
…	…	…	…
…	…	…	…

CSP Planning: Constraints Contd.

Other constraints we may want are action constraints:

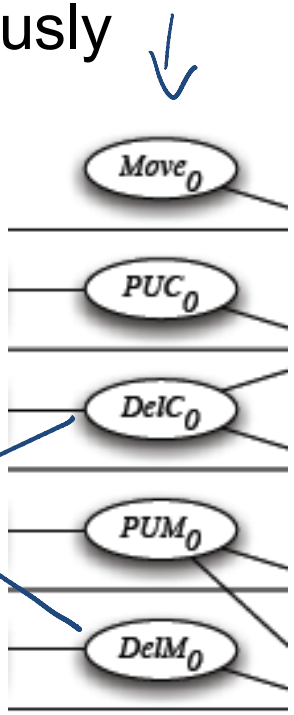
- specify which actions cannot occur simultaneously
- these are sometimes called mutual exclusion (mutex) constraints

E.g., in the Robot domain

DelM and *DelC* can occur in any sequence (or simultaneously)

But we could change that…

$DelM_i$	$DelC_i$
T	F
F	T
F	F

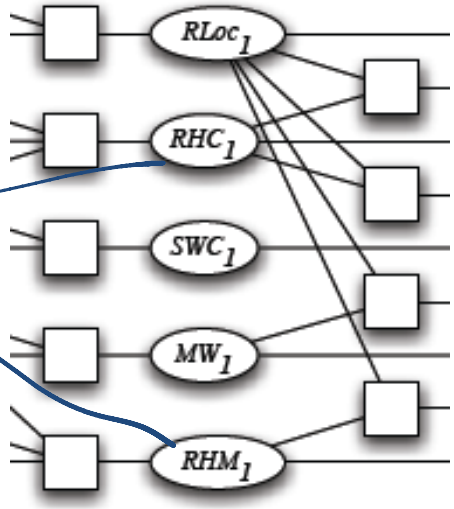


CSP Planning: Constraints Contd.

Other constraints we may want are state constraints

- hold between variables at the same time step
- they can capture physical constraints of the system (robot cannot hold coffee and mail)
- they can encode maintenance goals

RHC_i	RHM_i
T	F
F	F
F	T



$State_1$

CSP Planning: Solving the problem

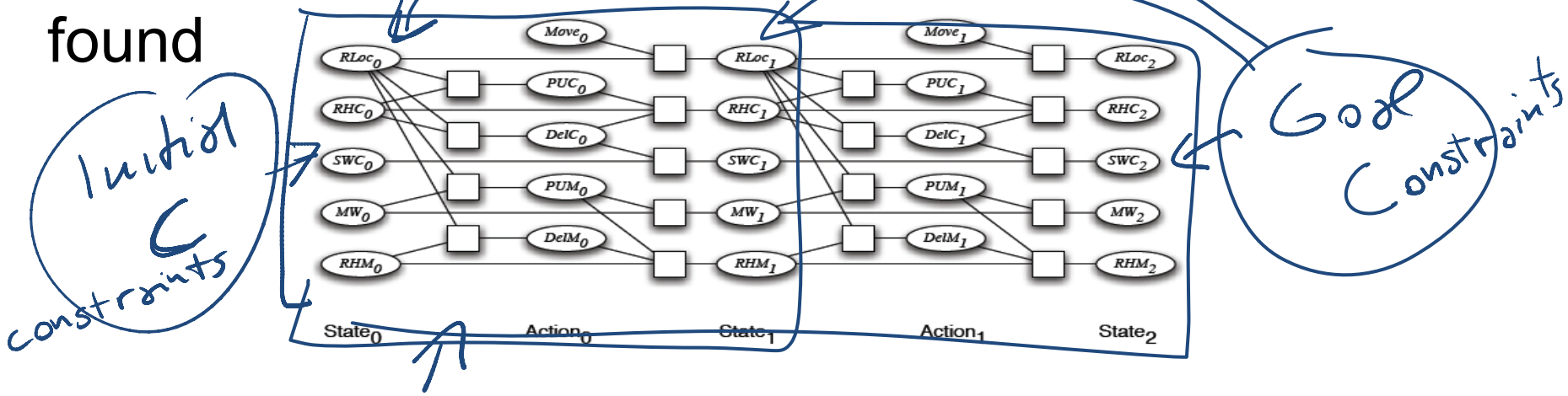
Map STRIPS Representation for horizon: 0, 1, 2 ....

Run **arc consistency**, **search**, **stochastic local search**!

Stop when solution to CSP is found

Plan: all actions with assignment T

In order to find a plan, we expand our constraint network one layer at the time, until a solution is found



Solve planning as CSP: pseudo code

```
horizon = 0
while not solved
    map STRIPS to CSP with horizon
    solve CSP -> solution
    if solution found then
        solved = true
    else
        horizon = horizon + 1
return solution
```

State of the art planner

A similar process is implemented (more efficiently) in the Graphplan planner

STRIPS to CSP

Under prototype applets

Allows you:

- to specify a planning problem in STRIPS
- to map it into a CSP for a given horizon
- the CSP translation is automatically loaded into the CSP applet where it can be solved

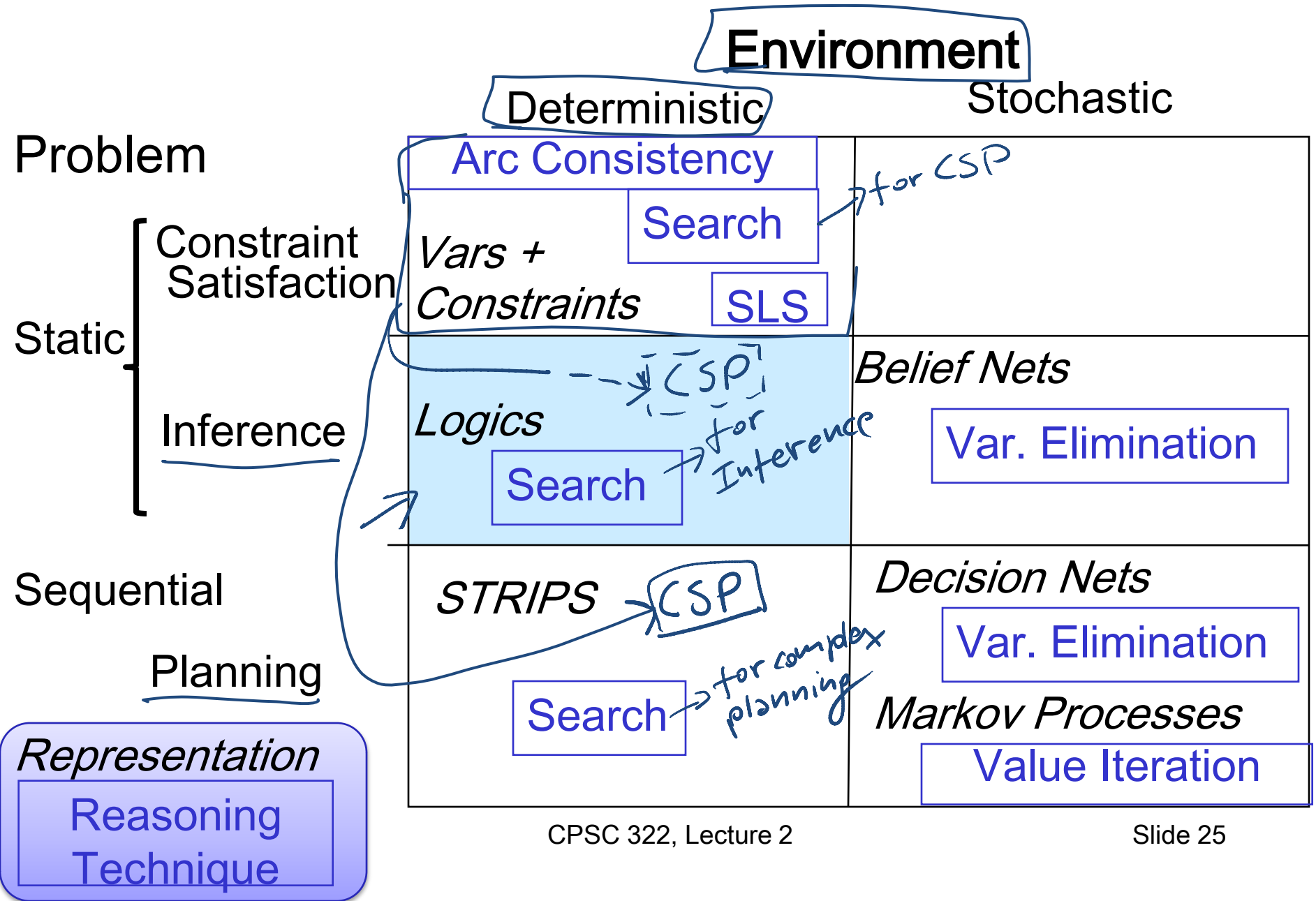
Practice exercise using STRIPS to CSP will be posted

Learning Goals for today's class

You can:

- Construct and justify a heuristic function for forward planning.
- Translate a planning problem represented in STRIPS into a corresponding CSP problem (and vice versa)

What is coming next ?



Logics

- **Mostly only propositional**…. This is the starting point for more complex ones ….
- **Natural** to express **knowledge** about the world
  - What is true (boolean variables)
  - How it works (logical formulas)
- Well understood formal properties
- Boolean nature can be exploited for efficiency
- ……

Coming up course elements

Today **Assign-1 returned**

Wed, February 25: **Assign-2 due**

- **Two programming exercises. Start asap. Work in pairs. If stuck, come to office hours (this week only Mon and Wed 2-3 learning center)**

Wed, March 4

Midterm exam (1.5 hours, regular room)